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**Unit 7, Part 2 Notes: More Complex Patterns of Inheritance**

Pre-AP Biology, Mrs. Krouse

**What is a test cross?**

1. A ***test cross*** is a method that scientists use when they have an organism with a dominant phenotype, but they are unsure whether it has a homozygous dominant genotype (ex: AA) or a heterozygous genotype (ex: Aa).
2. In the test cross, scientists cross (mate) this organism (Organism 1) with another organism (Organism 2) that shows the recessive phenotype. Organism 2 must have the homozygous recessive genotype (ex: aa) to display the recessive phenotype.
3. In a typical Punnett square problem, you are given information about the parents and use the Punnett square to predict offspring genotype and phenotype frequencies. With a test cross problem, you are given information about the offspring phenotype frequencies, and you must infer the genotype (homozygous dominant or heterozygous) of the parent with the dominant phenotype (Organism 1).
4. For example, let’s say a test cross tracks the inheritance of the trait of height. The dominant phenotype is tall, and the recessive phenotype is short. We will use “A” to represent the tall allele and “a” to represent the short allele.

|  |  |  |
| --- | --- | --- |
|  | **A** | **A** |
| a | Aa | Aa |
| a | Aa | Aa |

1. If all (100%) of the offspring in the test cross show the dominant trait (i.e., tall), then Organism 1 must have had the homozygous dominant genotype (AA). The Punnett square that shows this result is given to the right. The genotype of Organism 1 is shown in bold.

|  |  |  |
| --- | --- | --- |
|  | **A** | **a** |
| a | Aa | aa |
| a | Aa | aa |

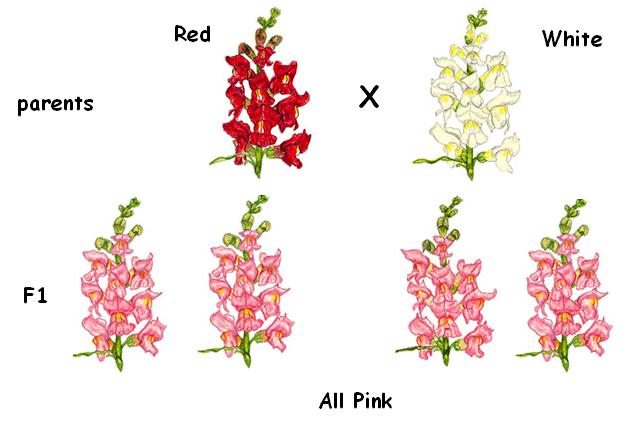
1. If half (50%) of the offspring in the test cross show the dominant trait (i.e. tall) and the other half of the offspring show the recessive trait (i.e. short), then Organism 1 must have had the heterozygous genotype (Aa). The Punnett square that shows this result is given to the right. The genotype of Organism 1 is shown in bold.

**What are some exceptions to simple dominance?**

1. So far, we’ve only looked at traits where one allele completely masks or covers up the other. We would say these traits are examples of ***complete dominance*** (also known as ***simple dominance***). With these traits, an organism that has a heterozygous genotype (ex: Aa) will show the dominant phenotype. Remember, having a heterozygous genotype means having two different alleles.
2. Next, we will look at traits that do not show simple dominance. There are three types of traits we will investigate—traits that show incomplete dominance, traits that show codominance, and traits for which there are multiple alleles. In this case, “multiple alleles” means more than two alleles.
3. With traits that show ***incomplete dominance***, organisms with a heterozygous genotype (i.e., two different alleles) will show a phenotype (physical trait) that displays a blend of the two alleles. For this reason, incomplete dominance is also called blending inheritance. In other words, these organisms will show a trait that is in between the two alleles (i.e., intermediate).
4. For example, let’s say there are two alleles for the trait of flower color. One allele codes for red flowers, while the other codes for white flowers. If this is a trait controlled by incomplete dominance, a heterozygous plant would have pink flowers (i.e., in between red and white).
5. Another example of incomplete dominance might involve two alleles for the trait of plant stem length. One allele codes for long stems while the other codes for short stems. A heterozygous plant would have medium-length stems.
6. Typically, we would represent both alleles with capital letters (ex: “R” for red flowers and “W” for white flowers) to indicate that neither allele is dominant over the other. Occasionally, you may see an example where one allele is represented with a capital letter, and the other allele is represented with a lowercase letter (ex: “R” for red and “r” for white). Using a capital and lowercase letter isn’t very accurate, however, because it implies that one allele is dominant over the other.

|  |  |  |
| --- | --- | --- |
|  | R | R |
| W | RW | RW |
| W | RW | RW |

1. To identify a trait as an example of incomplete dominance and conduct a Punnett square analysis using this trait, you would need to be told what phenotype (i.e. physical trait) resulted from each genotype (i.e., combination of alleles). For example, I would need to tell you that a plant with a red flower allele and a white flower allele will have pink flowers. Another way to say this is that the offspring of a purebred red-flowered plant and a purebred white-flowered plant will have pink flowers. (Remember, purebred is another way to say homozygous, which means the plant has two of the same allele. A purebred red-flowered plant will have the genotype RR, and a purebred white flowered plant will have the genotype WW. All offspring from this cross will have the genotype RW, which is shown in the Punnett square to the right. When we use two different letters to represent alleles, we always write the letter that is earlier in the alphabet first.)



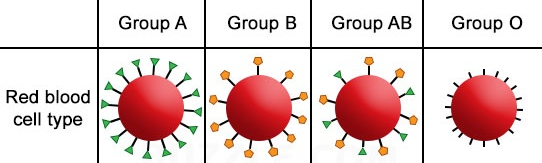
1. With traits that show ***codominance***, organisms with a heterozygous genotype (i.e., two different alleles) will show a phenotype (physical trait) that displays both alleles in their pure form. In other words, you will see both traits clearly, not a blend of the two traits.



1. Let’s go back to our example trait (flower color). Remember, one allele codes for red flowers, while the other codes for white flowers. If this is a trait controlled by codominance and not incomplete dominance, a heterozygous plant may have flowers with patches of red and white. Both the red and white flower allele show up clearly.
2. Another example of codominance might involve two alleles for the trait of hair texture in an alien species. (I don’t know, I’m making this up as I go!). One allele codes for straight hair while the other codes for curly hair. A heterozygous alien would have some hair strands that are straight and some that are curly.
3. Just like with incomplete dominance, with codominance we would typically represent both alleles with capital letters (ex: “S” for straight hair and “C” for curly hair) to indicate that neither allele is dominant over the other. Occasionally, you may see an example where one allele is represented with a capital letter, and the other allele is represented with a lowercase letter (ex: “S” for straight hair and “s” for curly hair). Using a capital and lowercase letter isn’t very accurate, however, because it implies that one allele is dominant over the other.

|  |  |  |
| --- | --- | --- |
|  | C | S |
| C | CC | CS |
| S | CS | SS |

1. To identify a trait as an example of codominance and conduct a Punnett square analysis using this trait, you would need to be told what phenotype (i.e. physical trait) resulted from each genotype (i.e., combination of alleles). For example, I would need to tell you that an alien with a straight hair allele and a curly hair allele will have some hair strands that are straight and some that are curly. Another way to say this is that the offspring of a purebred straight-haired alien and a purebred curly-haired alien will have some hair strands that are straight and some that are curly. Suppose I gave you that information and asked you to cross two aliens that are heterozygous for the trait of hair texture. Both of these aliens will have the genotype CS (according to the allele abbreviations we specified at the beginning of #17). Note that I have again listed the alleles for this heterozygous genotype in alphabetical order (C comes before S in the alphabet). From this cross (see Punnett square to the right), 25% of the offspring will have the genotype CC, which means they will have the phenotype of curly hair. 50% of the offspring will have the genotype CS, which means they will have the phenotype of some hair strands that are straight and some that are curly. 25% of the offspring will have the genotype SS, which means they will have the phenotype of straight hair.
2. When the inheritance of a trait is determined by ***multiple alleles***, this means there are more than two alleles for a particular trait. For you to solve a Punnett square problem involving multiple alleles, I would need to tell you what the alleles are and how they interact with one another. When I say “interact,” I mean is one allele dominant over the others? Do some of the alleles display codominance or incomplete dominance?
3. One example of multiple alleles controlling a trait is the ABO blood group system. Humans can have four different blood types—A, B, AB, and O. These phenotypes (i.e., blood types, which are physical traits), are displayed in the form of small molecules called antigens on the surface of red blood cells. There are two types of antigens—Antigen A and Antigen B.
4. People with blood type A show Antigen A on the surface of their red blood cells. In the image below, Antigen A molecules look like triangles.
5. People with blood type B show Antigen B on the surface of their red blood cells. In the image below, Antigen B molecules look like pentagons (five-sided shapes).
6. People with blood type AB show some Antigen A molecules and some Antigen B molecules on the surface of their red blood cells.
7. People with blood type O show no antigens on the surface of their red blood cells.



1. For the ABO gene, the O allele is recessive to both the A and B alleles. This means people who have the genotype AO will show type A blood. Similarly, people who have the genotype BO will show type B blood. Only people who have the genotype OO will show type O blood.
2. The A and B alleles are codominant to each other, which means people who have the genotype AB (and therefore the blood type AB) will show both alleles clearly. In other words, they will have some Antigen A molecules and some Antigen B molecules on the surface of their red blood cells.
3. Sometimes scientists use a different allele coding system for the A, B, and O alleles to better show their interactions with one another. O is given the abbreviation “i” to show that it is recessive to both the A and B alleles. The A and B alleles are given the abbreviations IA and IB. The presence of the capital “I” indicates that they are dominant to O. The presence of a capital A and capital B indicate that these alleles are codominant to each other. For the purposes of our class, however, we will simply use the letters A, B, and O to represent the alleles.
4. Each possible genotype (two allele combination) and phenotype (physical trait) is given in the chart below.

|  |  |
| --- | --- |
| **Genotype** | **Phenotype** |
| AA | Blood Type A |
| AO | Blood Type A |
| BB | Blood Type B |
| BO | Blood Type B |
| AB | Blood Type AB |
| OO | Blood Type O |

1. In a Punnett square problem about blood types, we would say that a person with the genotype AO is heterozygous for blood type A. Remember, being heterozygous means that you have two different alleles for a particular trait. A person with the genotype AA is homozygous for blood type A. Remember, being homozygous means that you have two of the same allele for a particular trait.
2. Similarly, a person with the genotype BO is heterozygous for blood type B, and a person with the genotype BB is homozygous for blood type B.

|  |  |  |
| --- | --- | --- |
|  | A | O |
| B | AB | BO |
| O | AO | OO |

1. Let’s say I told you that a man who is heterozygous for blood type A and a woman who is heterozygous for blood type B marry and have children. You are asked to create a Punnett square for this situation and predict the blood types (phenotypes) of their potential offspring. The correct Punnett square is shown to the right. 25% of the offspring will have blood type A, 25% will have blood type B, 25% will have blood type AB, and 25% will have blood type O.